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著者
KURITA Susumu, NAGASAWA Isao, TANAKA Kunihide, NISHINA Yuichiro, FUKUROI Tadao

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Infrared Absorption and Faraday Effect
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Susumu Kurita, Isao Nagasawa**, Kunihide Tanaka,
Yuichiro Nishina and Tadao Fukuroi

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Synopsis

Free carrier absorption and Faraday effect in p-type PbSe, n- and p-type PbTe were measured in the wavelength range from 3 to 15 microns at room temperatures. The effective masses of electrons for PbTe and of holes for PbSe were deduced to be 0.11 m_e and 0.14 m_h, respectively, and the ratios of the longitudinal to the transverse masses associated with the ellipsoidal energy surfaces were evaluated. It was concluded that four equivalent extrema exist along <111> directions on the hole energy surface of PbSe, and this result is consistent with the similarity between the absorption characteristics of p-type PbSe and that of n-type PbTe.

I. Introduction

The electronic band structure of the lead salts has been studied by a number of workers(1) since Irie(2) carried out the electrical measurements with PbS in 1956. There has been, however, no good quantitative agreement among these numerical values of the band parameters.

The present study was intended to determine the effective mass and the ratio of the transverse to the longitudinal mass by examining the following properties of both n- and p-type PbTe and of p-type PbSe:
(a) the electrical resistivity and the Hall coefficient;
(b) the infrared absorptions due to the free carrier and to the interband transition;
(c) the infrared Faraday effects due to the free carrier and to the interband transition.

The measurements of the properties mentioned in (a) are essential for the evaluation of the energy band parameters from the results of those in (b) and (c).

It is shown in the classical dispersion theory(3) that the free carrier absorption coefficient, \( \alpha \), and the free carrier Faraday rotation, \( \theta \), are given by

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** Present address; Research Laboratory, Iwasaki Communication Apparatus Co., Ltd., Hachioji, Tokyo.
\[ \alpha = \frac{Ne^3 \lambda^2}{4\pi^2 n c^3 \varepsilon_0 \mu m_{eF}^*} , \]  

(1)

and

\[ \theta = -\frac{Ne^3 B d \lambda^2}{8\pi^2 n c^3 \varepsilon_0 m_{eF}^*} , \]  

(2)

where \( N \) is the carrier density, \( \lambda \) the wavelength in a free space, \( n \) the refractive index in the absence of the magnetic field and \( B \) the magnetic induction, \( m_{eF}^* \) is the effective mass obtained from the optical absorption and \( m_{eF}^* \) is that obtained from the Faraday effect. In Eq. (2), the plus sign of \( \theta \) corresponds to the rotation of the plane of polarization in counter-clockwise for an observer who looks against the direction of propagation of radiation.

\( \alpha \) and \( \theta \) are proportional to the square of the wavelength and inversely proportional to the square of the effective mass, \( m^* \). Hence, the effective mass may be evaluated both from the absorption coefficient and from the Faraday effect. Moreover, since the sign of \( \theta \) is opposite to that of the charge carrier, it can be discriminated from the direction of the Faraday rotation whether the free carrier is electron or hole, provided that only one kind of carrier participates in the effect.

**II. Apparatus and procedures**

The apparatus for the measurement of absorption is illustrated schematically in Fig. 1. The radiation from a globar lamp \( S_1 \) is divided into two beams; one of

![Fig. 1. The optical arrangement for absorption and reflection measurements.](image)

which is passed through the specimen and the other (reference beam) through a comb-shaped attenuator. Both beams are chopped at a frequency of 8 c/sec by the same chopper C and focussed together on the entrance slit of the monochro-
mator. The spectrometer contains a Carl Leiss double monochromator with rock salt prisms. The monochromatic radiation is detected by a vacuum thermocouple with a KBr window. The detected signal is amplified by dint of a narrow band amplifier. The amplified signal drives the servomotor which in turn being mechanically coupled with the comb-shaped attenuator.

The displacement of the attenuator was converted into a d.c. voltage across a helicalohm which was mechanically coupled with the attenuator and the d.c. output was fed to a pen recorder. If necessary, the same spectrometer could be used for the reflection measurement with replacement of the light source $S_1$ by $S_2$. The resolution of this spectrometer is $6 \text{ cm}^{-1}$ at $\lambda = 6 \mu$. This resolution is not so good, but sufficient for the present object for detecting the wavelength dependence of the free carrier and interband absorptions. All measurements were carried out in a dry nitrogen atmosphere.

The apparatus for the Faraday effect measurement is schematized in Fig. 2. The electric current through the light source $S$ was stabilized within $\pm 0.25\%$ by an automatic voltage regulator. After being reflected by the mirrors $M_1$, $R_1$ and $M_2$, the radiation from the source was chopped at 8 c/sec by a mechanical chopper and was focussed on the Carl Leiss monochromator.

Monochromatic radiation incident at the Brewster angle was polarized by the vacuum-evaporated selenium film on a glass. The radiation beams reflected by a spherical mirror $R_2$ were not exactly parallel, nevertheless the deviation in the angle of incidence from the Brewster angle was estimated to be $\pm 3 \text{ deg.}$ at most.

In order that the radiation might propagate parallel to the magnetic induction,
the axial holes were bored through the yokes and pole pieces of the electromagnet. The size of the hole on the pole pieces is 12 mm × 3 mm. The intensity of the magnetic field was measured by a gaussmeter manufactured by the Empire Scientific Corp. with an accuracy better than ±2%.

The inhomogeneity of the magnetic field over the area of the specimen 1 mm × 10 mm was ±4%. The measurement of the Faraday effect was carried out at 12 kgauss.

After leaving the specimen, the radiation passed through an analyzer which consisted of a pile of six sheets of AgCl plates. The direction of light propagation was deflected by the AgCl plates, so that the position of the image of source on the detector was slightly shifted. Since the sensitive area of a vacuum thermocouple detector was small (0.3 mm × 2.5 mm), the intensity of the light emerged from the analyzer deviated slightly from cos^2 β characteristic, β being the angle between the polarized plane of light and the axis of analyzer.

When the magnetic field was applied, the optical signal on the detector changed because of the Faraday rotation. Before the field was turned on, the analyzer was set at 45° to the plane of polarization of the radiation, and then the angle of the Faraday rotation was measured by a kind of null method, so that the analyzer was rotated to compensate the change of signal on the detector after the field was turned on. In this arrangement for measuring the Faraday rotation, the smallest detectable angle of rotation was half a degree.

III. Preparation of specimens

1. Lead telluride specimens

Single crystals of lead telluride were prepared by a usual Bridgman method. Stoichiometric amounts of lead and tellurium were weighed and vacuum-sealed in a transparent fused quartz crucible. Both lead and tellurium were 99.9999% in purity and were obtained from the Asahi Metals Co. The crucible was heated at about 980°C for 60 hours in an electric furnace and was lowered through the region of the temperature gradient (13°/cm) near the solidifying point in the furnace, at the rate of about 2.5 mm/hour.

The crystals obtained were of p-type and contained about 2 × 10¹⁸ cm⁻³ holes. The crystal orientation was determined by cleaving along {100} faces, and the crystals were cut to the size of 3 mm × 9 mm × 12 mm with a razor blade. The p-type PbTe specimen was turned into n-type one by annealing for 750 hours in a lead vapor at 600°C. The specimens of both types were cleaved into three ingots, of which the middle portion was used for the electrical measurement and the others for the optical measurements. In order to prepare the specimens for the optical measurements, one face was first ground along the (100) cleavage plane with a fine powder of carborundum, and then the ground plane was glued on a glass plate of optical flat with a compound of bee's wax and resin. The unevenness of the optical flat was found by Newton's ring test to be less than 0.5μ within an area of 50 mm ×
50 mm. Specimens were mounted on the optical flat and then worn down to the desired thickness with polishing powder of tin oxide on a pitch lap covered with silk cloth. The fine grains of polishing powder were obtained by the precipitation in about three hours in the liquid skimmed from an original mixture of tin oxide powder and water.

The uniformity of the specimen thickness was secured by gluing four similar pieces on the corners of an optical flat. The specimen surface glued on the optical flat was polished in the same way until some interference fringes were observed in the sunlight incident on the specimen surface through another plate of optical flat glass. The uniformity of the specimen thickness within $\pm 5 \mu$ was obtained for an area of $10 \text{mm} \times 3 \text{mm} \times 0.080 \text{mm}$ by this procedure. The thickness itself was measured directly with a dial gauge of $1 \times 10^{-2} \text{mm/division}$ and was checked by weighing with the value of density reported in the literature\(^{(4)}\). It was difficult to prepare the PbTe specimen thinner than $50 \mu$ as it cleaved easily.

2. Lead selenide specimens

The preparation of PbSe specimen was quite similar to that of PbTe except for the following conditions:

1) The original purity of selenium obtained also from the Asahi Metals Co. was better than 99.999\%.

2) The temperature in the middle of the electric furnace had to be kept at 1150°C.

**IV. Experimental results**

1. The electrical resistivity and the Hall coefficient

<table>
<thead>
<tr>
<th>Sample and type</th>
<th>295°C</th>
<th>77°C</th>
<th>4.2°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$N$</td>
<td>$\rho$</td>
<td>$\mu_H$</td>
</tr>
<tr>
<td>p-PbTe No.1</td>
<td>2.04</td>
<td>$3.67 \times 10^{18}$</td>
<td>$8.35 \times 10^9$</td>
</tr>
<tr>
<td>p-PbTe No.2</td>
<td>1.68</td>
<td>$4.35 \times 10^{16}$</td>
<td>$8.43 \times 10^9$</td>
</tr>
<tr>
<td>n-PbTe No.1</td>
<td>3.58</td>
<td>$1.16 \times 10^{16}$</td>
<td>$1.50 \times 10^9$</td>
</tr>
<tr>
<td>n-PbTe No.2</td>
<td>3.10</td>
<td>$1.39 \times 10^{16}$</td>
<td>$1.45 \times 10^9$</td>
</tr>
<tr>
<td>p-PbSe No.1</td>
<td>2.87</td>
<td>$3.17 \times 10^{18}$</td>
<td>$7.39 \times 10^9$</td>
</tr>
<tr>
<td>p-PbSe No.2</td>
<td>2.35</td>
<td>$2.66 \times 10^{18}$</td>
<td>$9.76 \times 10^9$</td>
</tr>
</tbody>
</table>

$N$: charge carrier density in cm$^{-3}$

$\rho$: resistivity in ohm-cm

$\mu_H$: Hall mobility in cm$^2$/volt sec

As seen in Eq. (1) or (2), either free carrier absorption or Faraday rotation experiment can give the value of the effective mass, provided that the values of the carrier density, the index of refraction and the mobility are known. It is the reason why the Hall coefficient and the resistivity of the specimens were first measured. The results are listed in Table 1.

Since several workers had studied the electrical properties of PbTe and PbSe, only main characteristics of the present results will be mentioned here. It may well be assumed that fair agreements between the previous results and the present ones have been observed unless otherwise stated.

![Graph](image)

Fig. 3 (a). Temperature dependence of the resistivity and the Hall coefficient of n-type PbTe with \( N = 3.67 \times 10^{17} \text{ cm}^{-3} \) at 77°C

\( \rho \): Resistivity  
\( R \): Hall coefficient

The temperature dependence of the resistivity, the Hall coefficient and the Hall mobility for an n-type PbTe specimen are shown in Fig. 3 (a) and (b). The Hall coefficient remains nearly constant from 4.2°C to 300°C. It decreases rapidly, however, above 330°C and reaches the intrinsic range. The temperature dependence
Fig. 3 (b). Temperature variation of the Hall mobility of n-type PbTe with 

\[ N = 3.67 \times 10^{17} \text{cm}^{-3} \] at 77°K.

of the Hall mobility is approximated by \( T^{-2/3} \) characteristic* between 50°K and 300°K. Even at the lowest temperature it continues to increase with falling temperature and attains to such a high value as \( 2.8 \times 10^6 \text{cm}^2/\text{v}. \text{sec} \) at 4.2°K. Such a temperature dependence seems to indicate that the effect of impurity scattering is very small. The temperature variations of the mobility and the Hall coefficient of p-type PbTe and PbSe are similar to those of n-type PbTe. The Hall coefficient for the carrier of the ellipsoidal energy surfaces with cubic symmetry is given by\(^6\)

\[
R = \frac{1}{Ne} \frac{\langle \tau^2 \rangle}{\langle \tau \rangle^2} \left[ \frac{3K(K+2)}{(2K+1)^2} \right],
\]

where \( K = m_i/m_e \) is the ratio of longitudinal to transverse mass and \( \tau \) the relaxation time of the charge carrier. \( \langle \tau^2 \rangle/\langle \tau \rangle^2 \) is a numerical factor which, assuming the acoustical scattering, varies between the limits \( 3\pi/8 \) and 1, corresponding to

* This temperature dependence is slightly different from the results of Shogenji and Uchiyama\(^5\), who found it to be \( T^{-2.5} \).


(6) Progress in Semiconductors, 8 (1957), 23 (A Heywood Book London (1964) edited by A.F. Gibson and Burgess)
classical and degenerate statistics, respectively. The value of $K$ can be obtained from the published works on the magnetoresistance studies. These values, however, are not in exact agreement with each other, but it seems that $3 < K < 6$ for both electron and hole in PbTe between 70°K and 300°K. The theoretical calculation by Dimmock and Wright(1) gives the conclusion that the values of $K$ for both electron and hole in PbSe are slightly larger than unity. For the above values of $K$, the quantity in the bracket in Eq. (3) lies between 0.92 and 0.85 for PbTe, and is almost unity for PbSe. For this reason, the numerical value for the term in the bracket becomes 0.9 for both types of PbTe and unity for p-type PbSe in the subsequent analysis of the Hall data. The carrier density can be calculated by Eq. (3), assuming $\langle \tau^2 \rangle / \langle \tau \rangle^2 = 1$, as the Hall coefficient is almost constant between 4.2°K and 300°K.

The results of the free carrier absorption and of the Faraday effect of both PbTe and PbSe were analyzed on the assumption that the carrier density is constant below room temperatures. For this reason the analysis was carried out with the values of the carrier density at 77°K. The slight change in the Hall coefficient of those materials is due probably to the change in statistics of the carrier and to an experimental error. Before evaluating the effective mass, it is worthwhile to check whether the present experimental condition is consistent with the approximation for weak magnetic field, $\omega \tau \ll 1$ (where $\omega = eB/\hbar m^*$) and $\omega \tau \gg 1$, for which Eqs. (1) and (2) are valid. $\omega \tau$ can be estimated from $B\mu_H/\epsilon$ experimentally. The mobility at room temperature is $0.8 \approx 1.5 \times 10^3 \epsilon m^2/v. \sec$ for PbTe and PbSe and the magnetic field is 10 kgauss, so that

$$\omega \tau = \frac{B \mu_H}{\epsilon} \approx 4 \times 10^{-2} \ll 1.$$  

Also, the assumption that $\omega \tau \gg 1$ can be verified experimentally from $\mu = e\tau/m^*$, provided that $m^*$ is equal to $m_0$. The result for PbTe and PbSe at room temperature is

$$\omega \tau \approx 1 \times 10^2 \gg 1,$$

if the wavelength is taken as 10 $\mu$.

2. The infrared absorption

The absorption was measured with one specimen of p-type PbSe and one of p-type PbTe and two of n-type PbTe. The absorption coefficient $\alpha (\text{cm}^{-1})$ can be calculated from the transmission ($T$) according to

$$T = (1 - r)^2 e^{-2\alpha d} / (1 - r^2 e^{-2\alpha d}), \quad (4)$$

where $d$ is the specimen thickness in cm and $r$ the reflectivity. On evaluating $\alpha$ in Eq. (4), $r$ given by $r = (1-n)^2/(1+n)^2$ was taken to be 0.50 for PbTe and 0.47 for Pb-

Se from the experimental results of Walton and Moss\(^8\). The wavelength variation of the reflectivity was deemed to be very small within the accuracy of the present measurements, so that it was assumed to be a constant. The evaluated values of \(\alpha\) as a function of wavelength are shown in Figs. 4 and 5.

![Graph of absorption coefficient vs. wavelength for n-type PbTe](image1)

**Fig. 4.** Free carrier absorption in n-type PbTe at 295°K.

![Graph of absorption coefficient vs. wavelength for p-type PbTe and PbSe](image2)

**Fig. 5.** Free carrier absorption in p-type PbTe and p-type PbSe at 295°K.

The absorption coefficient for p-type PbTe specimen was about twelve times as large as that for n-type PbTe at 4.8\(\mu\). The absorption coefficient of p-type PbTe did not indicate the \(\lambda^2\)-dependence at long wavelength, whereas those of n-type PbTe and p-type PbSe indicated the \(\lambda^2\)-dependence at the range longer than 10
and $6\mu$, respectively. Therefore, the absorption for n-type PbTe or for p-type PbSe at the above-mentioned wavelengths might be considered to be due to the contribution only from the free carrier. Then, the effective mass for the electron in PbTe or for the hole in PbSe can be calculated from Eq. (1) with the values of mobility and carrier density obtained from the electrical measurements.

If the index of refraction is taken $n=5.76$ at $10\mu$ for PbTe and $n=5.74$ at $10\mu$ for PbSe\(^8\), the effective mass for the electron in PbTe and for the hole in PbSe are found to be

$$m_{ep}^* = (0.08 \pm 0.01) m_0 \quad \text{at 295°K} \quad \text{for n-PbTe No. 1 and No. 2},$$

and

$$m_{ep}^* = (0.10 \pm 0.01) m_0 \quad \text{at 295°K} \quad \text{for p-PbSe No. 1}.$$

The absorption coefficient for n- and p-type PbTe increases rapidly at wavelengths shorter than $4\mu$, and that for p-type PbSe also shorter than $5\mu$. These behaviors seem to be due to the excitation of electron from the valence band to the conduction band. From the above consideration the energy gap ($E_g$) between these bands is found for PbTe as

![Graph showing specific rotation vs. square of wavelength.](image)

Fig. 6. Free carrier Faraday effect in n-type PbTe at 298°K.
\[ E_g = (0.314 \pm 0.005) \text{ eV} \quad \text{at } 295^\circ \text{K} \]

and for PbSe

\[ E_g = (0.271 \pm 0.005) \text{ eV} \quad \text{at } 295^\circ \text{K} \]

These transitions correspond to the direct transition in the cases of PbTe and PbSe.

3. The Faraday effect

The experimental result of the Faraday effect for two specimens of n-type PbTe is shown in Fig. 6 where the magnetic field is applied in [100] direction. The angle of rotation is proportional to the square of wavelength in the range longer than 10\(\mu\). The rotation in this range is considered to be due to free carrier inasmuch as the Faraday rotation and the absorption coefficient in the same range both show the \(\lambda^2\)-dependence. The effective mass obtained from Eq. (2) for the electron of PbTe becomes

\[ m_e^* = (0.110 \pm 0.005) m_0 \quad \text{at } 295^\circ \text{K} \]

The result of the Faraday effect of p-type PbTe and PbSe specimens is given in

![Graph showing Faraday effect in PbTe and PbSe at 294°C.](image)

**Fig. 7.** Faraday effect in p-type PbTe and p-type PbSe at 294°C.
Fig. 7. The wavelength dependence of the effect in p-type PbSe is similar to that in n-type PbTe, so that the value of effective mass for the hole in PbSe is obtained as

\[ m_r^* = (0.139 \pm 0.005) m_0. \]

(at 294°C K

p-PbSe No. 1)

Since the absorption coefficient for p-type PbTe is large and the Faraday effect is small at long wavelength, it is very difficult to measure the angle of rotation. In the neighborhood of the absorption edge, however, the Faraday effect increases sharply, but such an increasing characteristic does not show the \( \lambda^2/(\lambda^2 - \lambda_0^2) \) variation as predicted by the classical theory.\(^{(3)}\) At this short wavelength range both p-type PbTe and PbSe show the same sign of the Faraday rotation, so that the effect due to free carriers is deduced to be much smaller than the effect due to the interband contribution. The sign of the angle of rotation in the neighborhood of the absorption edge is the same as that of n-type free carrier Faraday rotation.

V. Discussion

The free carrier absorption for the electrons in n-type PbTe shows the square dependence on the wavelength between 10\( \mu \) and 15\( \mu \) as given by Eq. (1). On the other hand, the hole in p-type PbTe does not show such a behavior in the same range of wavelength. In addition to such a difference in the wavelength dependence, the absorption coefficient in p-type PbTe is much larger than that in n-type PbTe at the wavelength in the neighborhood of 5\( \mu \). Such a difference in the absorption characteristic seems to indicate that the valence band of PbTe is much more complicated than the conduction band. The non-square wavelength dependence may be explained by a model that the valence band consists of one spherical valley at the center of the Brillouin zone and of four prolate ellipsoidal valleys in \( \langle 111 \rangle \) directions.\(^{(9),(10),(11),(12)}\) This behavior in the p-type specimen has been observed and also discussed by Riedl\(^{(13)}\) who estimated the magnitudes of the contribution from additional mechanism of absorption other than the free carrier and the direct interband transition.

From the free carrier Faraday effect measurement the effective mass of electrons in PbTe is found to be 0.11 \( m_0 \) when the field is applied in [100] direction. This result is in good agreement with that of the similar experiment by Walton and Moss.\(^{(8)}\)

The conduction band of PbTe has been known to consist of four prolate ellipsoidal valleys at the Brillouin zone edge in \( \langle 111 \rangle \) directions. On the other


hand, for the material with the four ellipsoidal energy surfaces along (111) directions and with the magnetic field along (100) axis, the effective mass, $m^*_F$, obtained from the Faraday effect is given by

$$m^*_F = m_t \left( \frac{3 K}{K + 2} \right)^{1/2}.$$  \hspace{1cm} (5)

If the number of equivalent valleys are given by $\gamma$, the density-of-state mass, $m^*_D$, is defined by

$$m^*_D = \gamma^{2/3} m_t K^{1/3}.$$ \hspace{1cm} (6)

From the definitions of the masses, $m^*_F$, and $m^*_D$, the mass ratio $K$ can be evaluated by combining Eq. (5) and Eq. (6), so that

$$\frac{m^*_D}{m^*_F} = \gamma^{2/3} K^{1/3} \left( \frac{3K}{K + 2} \right)^{-1/2}.$$ \hspace{1cm} (7)

According to the thermoelectric power measurement by Gershtein et al.\textsuperscript{(14)}, $m^*_D$ is given as $0.33 m_0$ for n-type PbTe. By putting this value of $m^*_D$ and the present result $m^*_F = 0.11 m_0$ into Eq. (7), we obtain $K = 3(\pm 2)$ for $\gamma = 4$ at room temperature. This value is almost consistent with Lydzens\textsuperscript{(7)} estimation $K = 3.5$.

Similar calculation can be carried out for holes in PbSe. Smirnov et al.\textsuperscript{(15)} reported from their thermoelectric power measurement that the value of $m^*_D$ to be $0.347 m_0$ in the concentration range $3.3 \times 10^{17}$ to $6.7 \times 10^{18} \text{cm}^{-3}$. From the present measurement of free carrier Faraday effect, $m^*_F = 0.139 m_0$ is obtained, so that $m^*_D/m^*_F = 2.50$. The number of equivalent valleys, $\gamma$, in the valence band of PbSe may be deduced from the following consideration. The value of $K^{1/3}(3K/(K + 2))^{-1/2}$ in Eq. (7) changes only from 1 to 1.36 as $K$ changes from 1 to 10. For $m^*_D/m^*_F = 2.50$, it is appropriate to take $\gamma = 4$, which leads to $K = 2(\pm 1)$ from Eq. (7). It should be noted that $K$ cannot be evaluated accurately from the measured values of $m^*_D/m^*_F$ since it changes very little even though the value of $K$ changes considerably.

The wavelength dependence of the free carrier absorption in p-type PbSe is similar to that of n-type PbTe as shown in Fig. 5. From the preceding discussion together with this absorption characteristic it may be concluded that the valence band extrema in PbSe are located at the Brillouin zone edges in (111) direction.

The effective mass evaluated from the free carrier absorption seems to show poor agreement with that from the free carrier Faraday effect. This discrepancy comes probably from the two reasons. First, the surface irregularity affects the apparent value of absorption coefficient and second, the scattering mechanism which


is responsible for the optical absorption may be different from that for the d.c. transport phenomena. On the other hand, the effective mass can be evaluated from the Faraday effect measurement without resort to the d.c. mobility measurement. Besides, the Faraday effect does not depend seriously on the surface treatment of the specimen. The mass value thus obtained, therefore, seems to be more reliable than that obtained from absorption measurement.

**Summary**

(1) The free carrier absorption and the Faraday effect in p-type PbSe and n- and p-types of PbTe were measured in the wavelength range from 3μ to 15μ at about 295°K. The measurements on the Faraday effect gave the electron effective mass of 0.11 \(m_0\) for PbTe \((N=3.1 \times 3.7 \times 10^{17}\text{cm}^{-3})\) and the hole effective mass of 0.14 \(m_0\) for PbSe \((N=2.7 \times 10^{18}\text{cm}^{-3})\).

(2) From the mass values cited above and from the results of thermoelectric power measurement by Gershtein et al., it was found that \(K=3(\pm 2)\) for electrons in PbTe and \(K=2(\pm 1)\) for holes in PbSe, \(K\) being the ratio of the longitudinal to the transverse mass associated with the ellipsoidal energy surface.

(3) It was deduced for PbSe from the hole effective mass given by Faraday effect and from the density-of-state mass by the thermoelectric power measurements that four equivalent extrema exist along \(\text{<111>}\) directions in the hole energy surface.

(4) The absorption characteristic of p-type PbSe is found to be rather similar to that of n-type PbTe than that of p-type one. Such a similarity in absorption characteristic is consistent with the above conclusion pertaining to the hole energy surface of PbSe.

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